Physics 122 – Class #10 – Outline

- Announcements
- Interference of light waves
  - Double slit
    - Diffraction Grating
  - Single slit
  - Interferometer

Reading – Next Week

ALL of Chapter 25 …

It is key to rest of course.

Main Concepts
Coulomb's Law
Charge
Electric Field

Applies to lab

Exam #1

Next THURSDAY 2/19/2014

… in CLASS

Covers Ch. 20, 21, 22, 23

Review Homework

Review Workbook (recitation questions)

One 3x5 card. One side. With equations only. No words / no pictures. Card submitted with exam.

Reading Question (Ch 22)

What was the first experiment to show that light is a wave?

A. Young's double-slit experiment.
B. Galileo's observation of Jupiter's moons.
C. The Michelson-Morley interferometer.
D. The Pound-Rebka experiment.
E. Millikan's oil-drop experiment.

Ch. 22: Interference and Diffraction

$d \sin\theta = m\lambda$

Condition for constructive interference between slits separated by "d".

$a \sin\theta = m\lambda$

Condition for destructive interference for single slit of width "a".

In general: Phase difference of 2 pi m or path difference of lambda, constructive interference.

Clicker Question

Light sources 1 and 2 are oscillating in phase emit sinusoidal waves. Point P is 7.3 wavelengths from source 1 and 4.3 from source 2.

As a result, at P there is

(A) Constructive interference.

(B) Destructive interference.

(C) Neither constructive nor destructive interference.

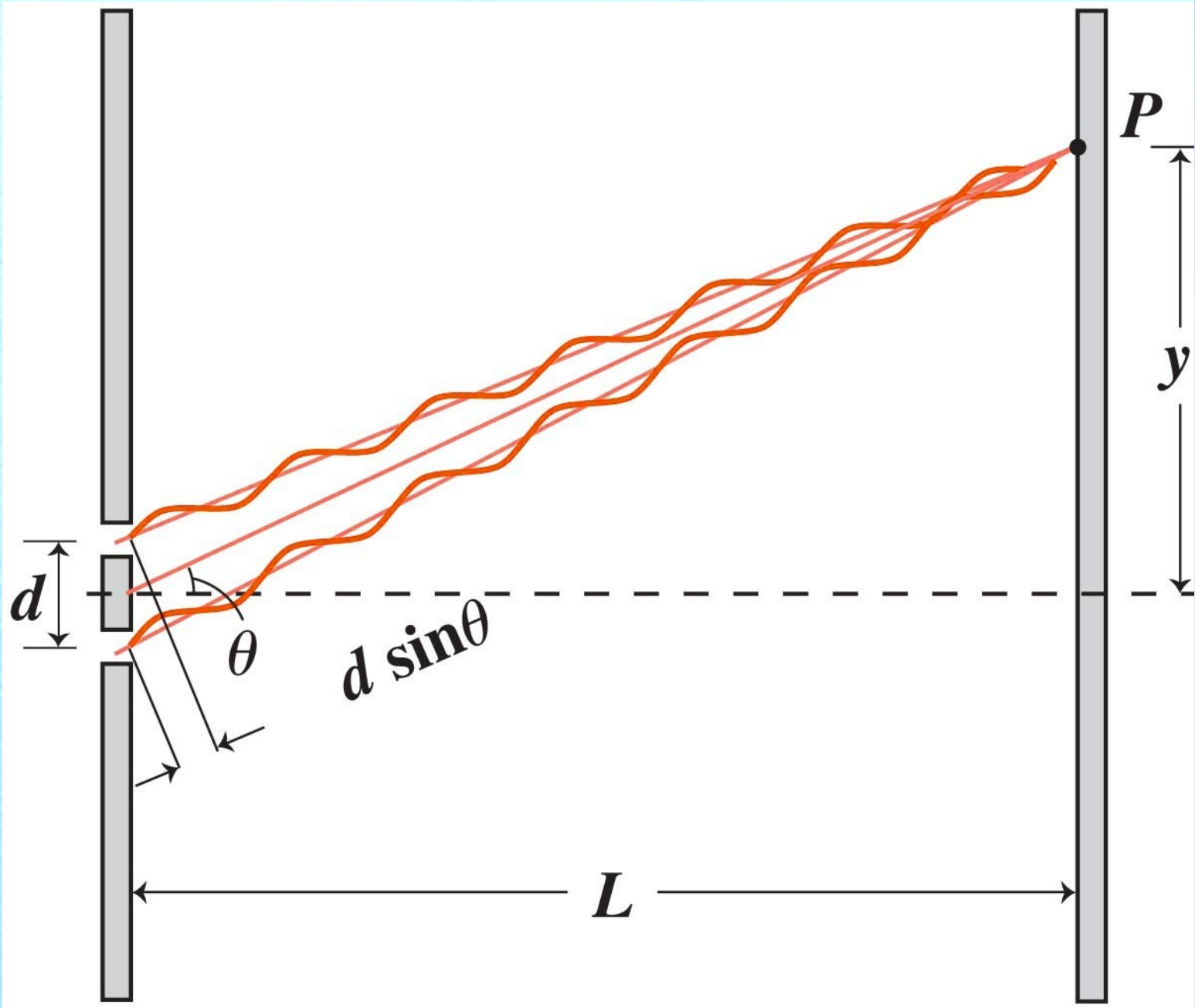
(D) Not enough information give to decide.

Double slit Constructive interference

$$d \sin\theta = m\lambda$$

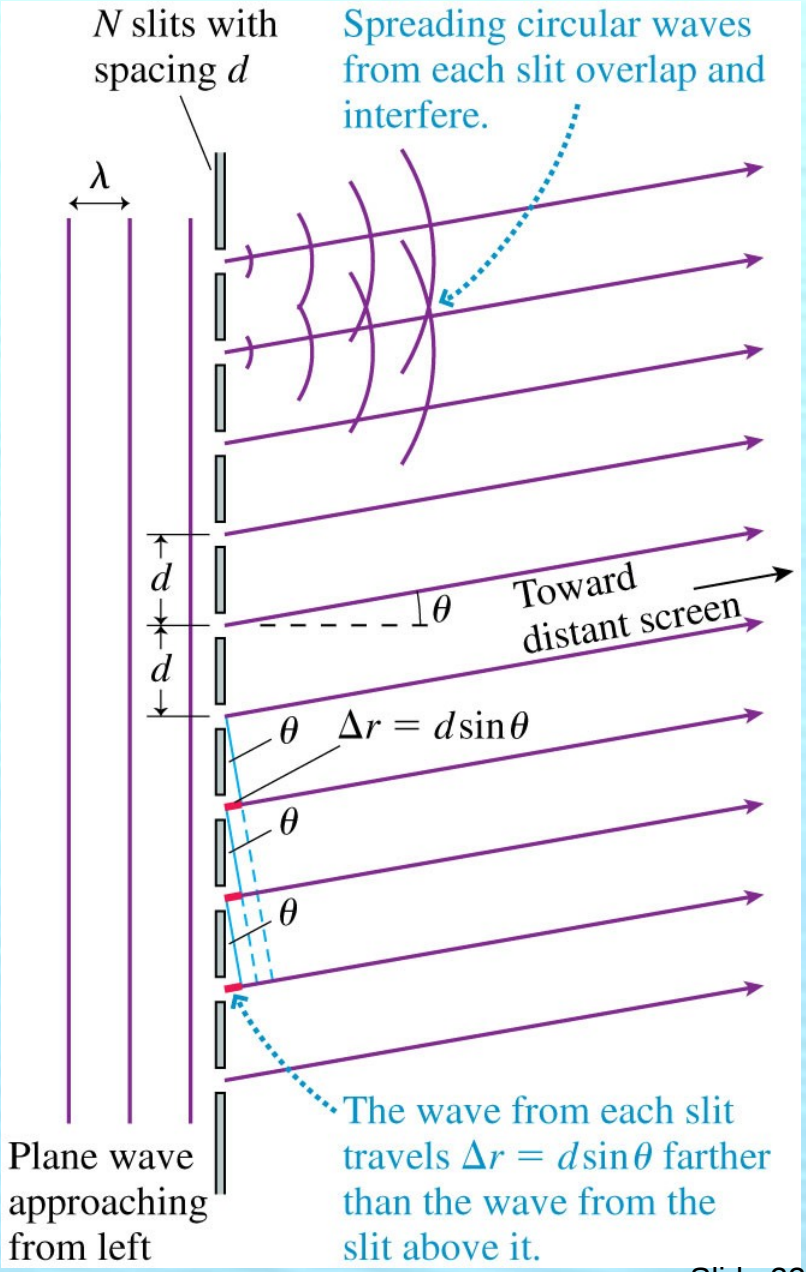
$$d\frac{y}{L} = m\lambda$$

$$y_{max} = m\lambda\frac{L}{d}$$

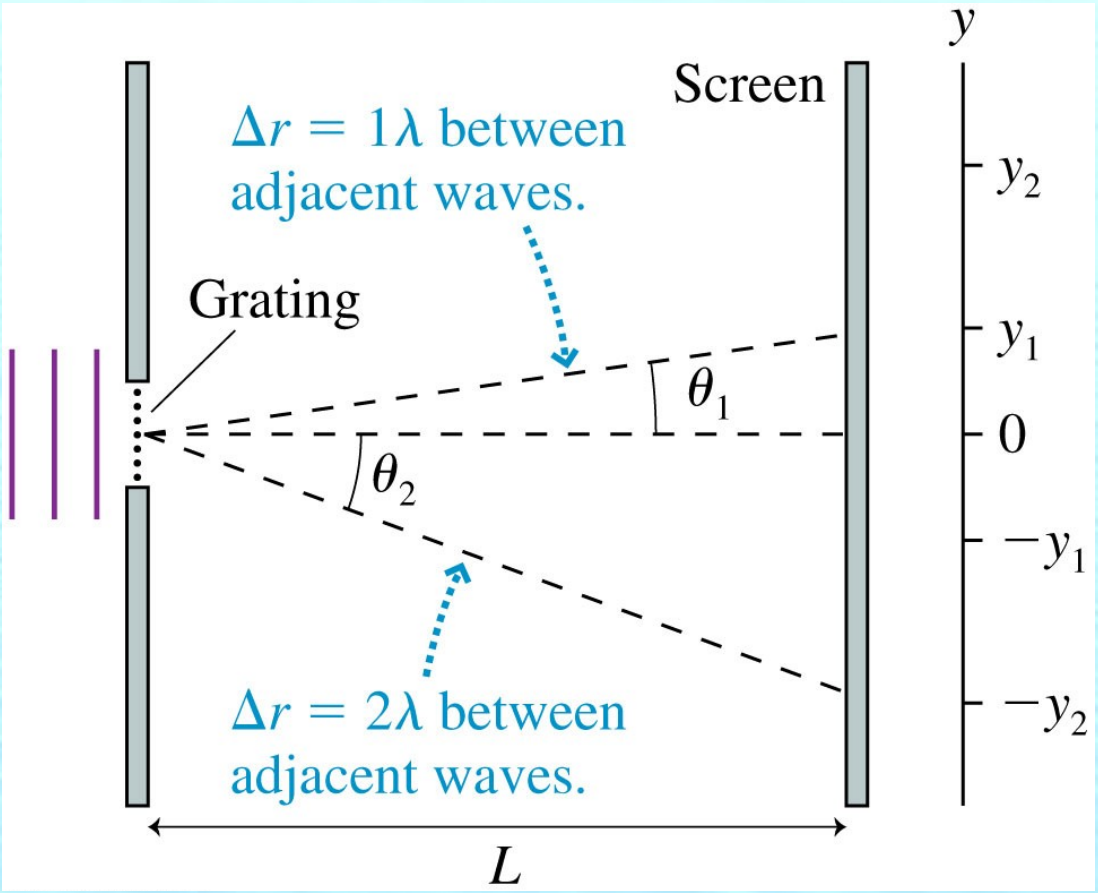


The Diffraction Grating

- The figure shows a diffraction grating in which N slits are equally spaced a distance d apart.
- This is a top view of the grating, as we look down on the experiment, and the slits extend above and below the page.
- Only 10 slits are shown here, but a practical grating will have hundreds or even thousands of slits.



Diffraction grating formula is same as double slit



Bright fringes will occur at angles ϕ_m, such that

$$d \sin\phi_m = m\lambda$$

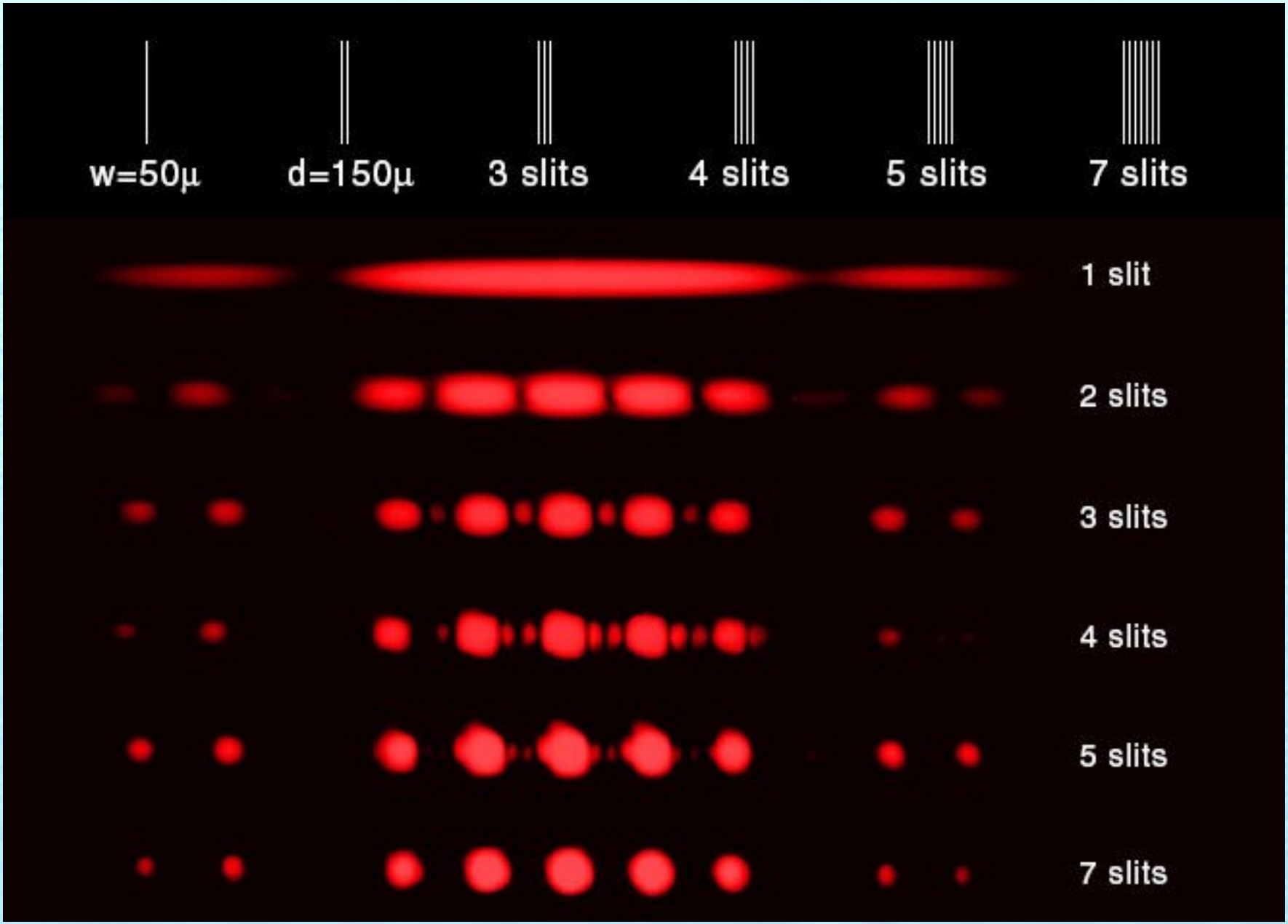
where $m = 0, 1, 2, 3, \ldots$

Note that gratings are Specified in "line per inch"

The y-positions of these fringes are:

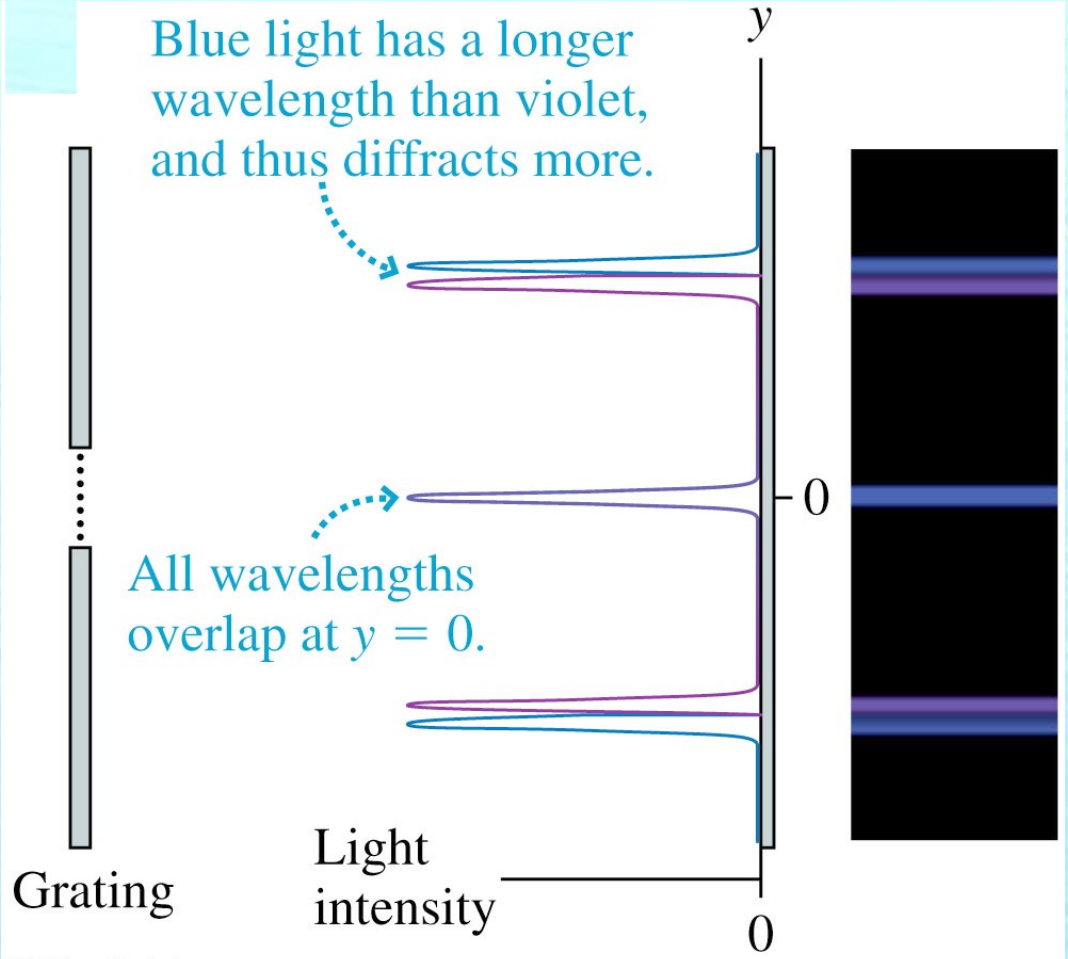
$$y_m = L \tan\theta_m \qquad \text{(positions of bright fringes)}$$

From single slit to diffraction grating ...

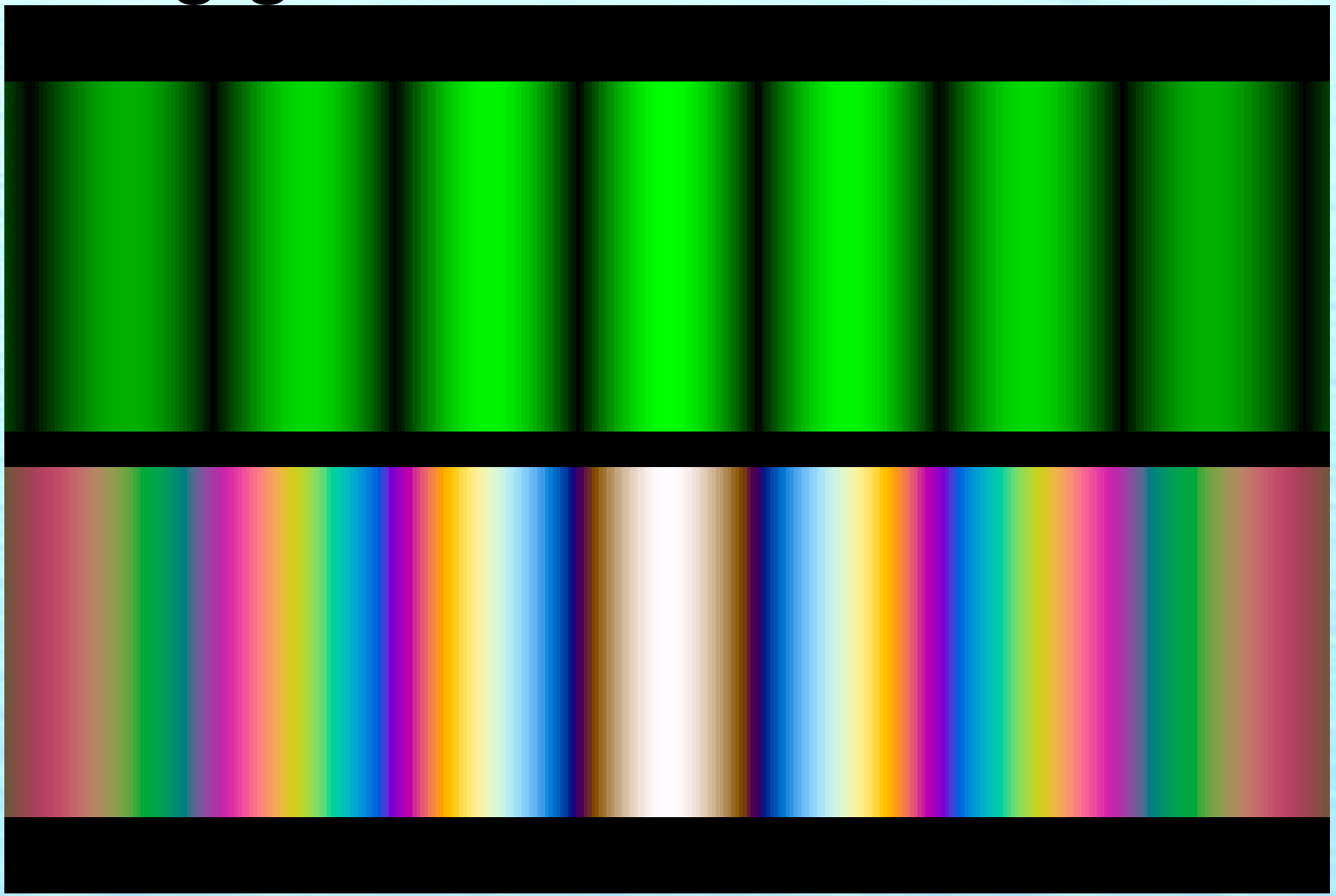


The Diffraction Grating

- Diffraction gratings are used for measuring the wavelengths of light.
- If the incident light consists of two slightly different wavelengths, each wavelength will be diffracted at a slightly different angle.



White light seen thru a diffraction grating gives rainbow bands



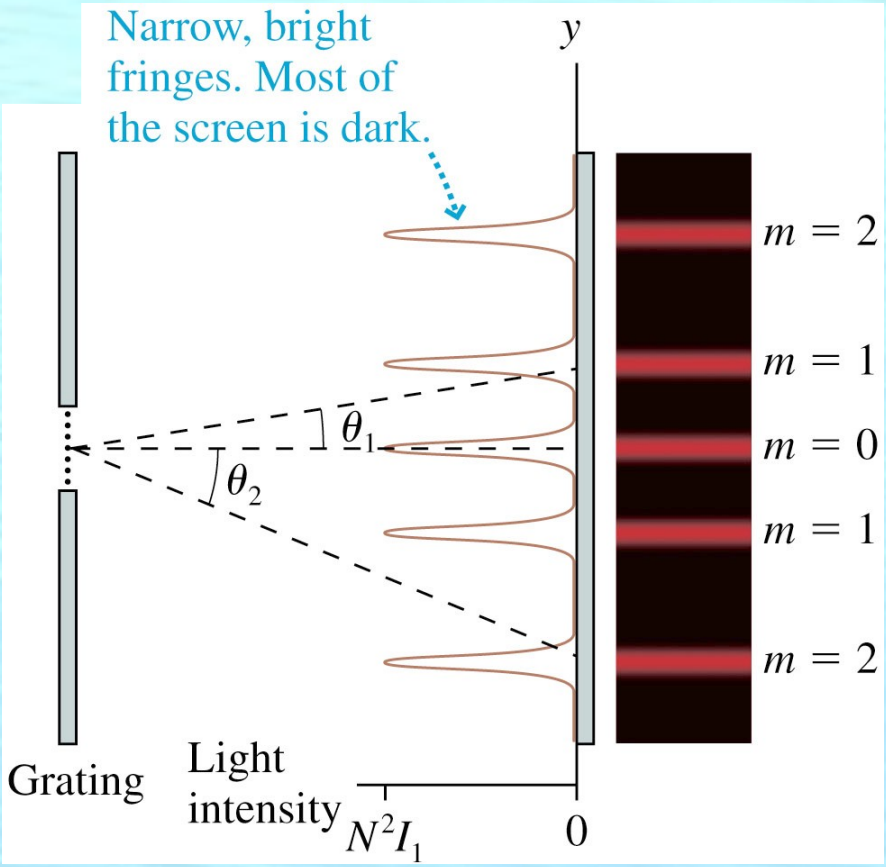
You frequently see a “reflection grating” In your daily life …

What is it?

The Diffraction Grating

- The integer m is called the **order** of the diffraction.
- The wave amplitude at the points of constructive interference is Na.
- Because intensity depends on the square of the amplitude, the intensities of the bright fringes are:
- By energy conservation, the dark regions between the spots should be bigger

$$I_{\max} = N^2 I_1$$



Homework 22.11

- Light of wavelength 600 nm illuminates a diffraction grating. The second-order maximum makes an angle of 39.5 degrees. How many lines per millimeter does the grating have?

Diffraction and small angle approximation

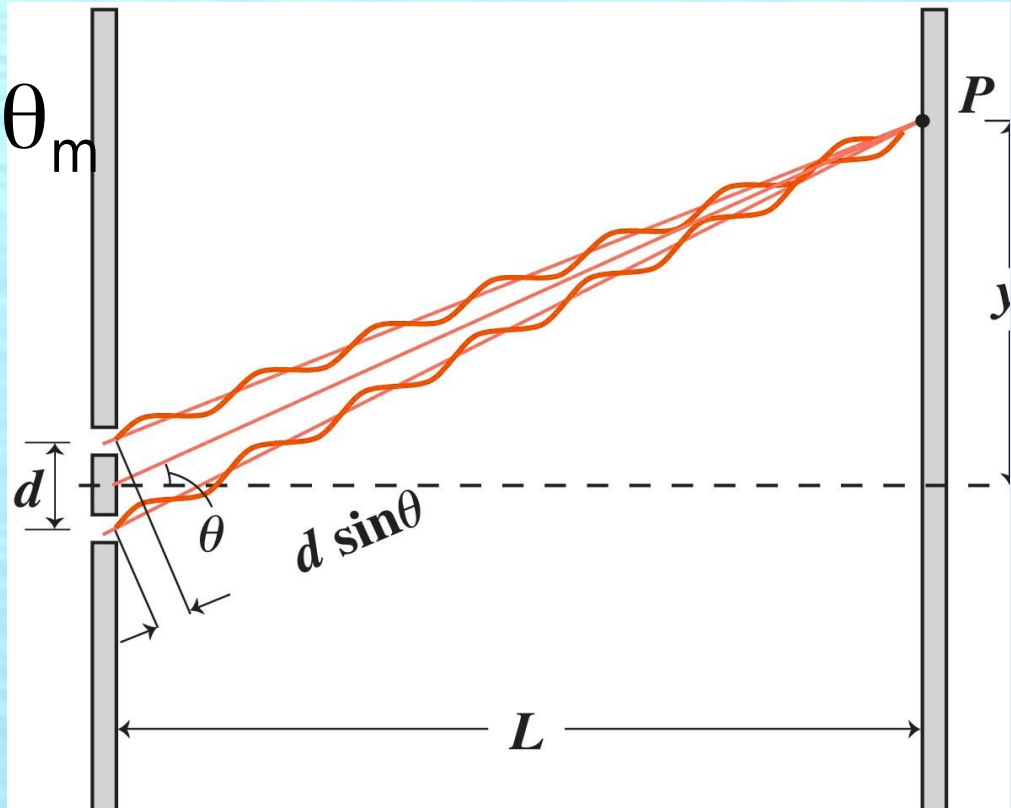
Exact: $d \sin\theta_m = m\lambda$

Approximate: $d\theta_m \sim m\lambda \rightarrow \theta_m = m\frac{\lambda}{d}$

Exact: $y_m = L\tan\theta_m$

Approximate: $y_m \sim L\sin\theta_m$

$$y_m \sim Lm\frac{\lambda}{d}$$



Taylor series and small angle approximation

$$\sin\theta = \theta - \frac{\theta^3}{3!} + \frac{\theta^5}{5!} - \frac{\theta^7}{7!} \ldots$$

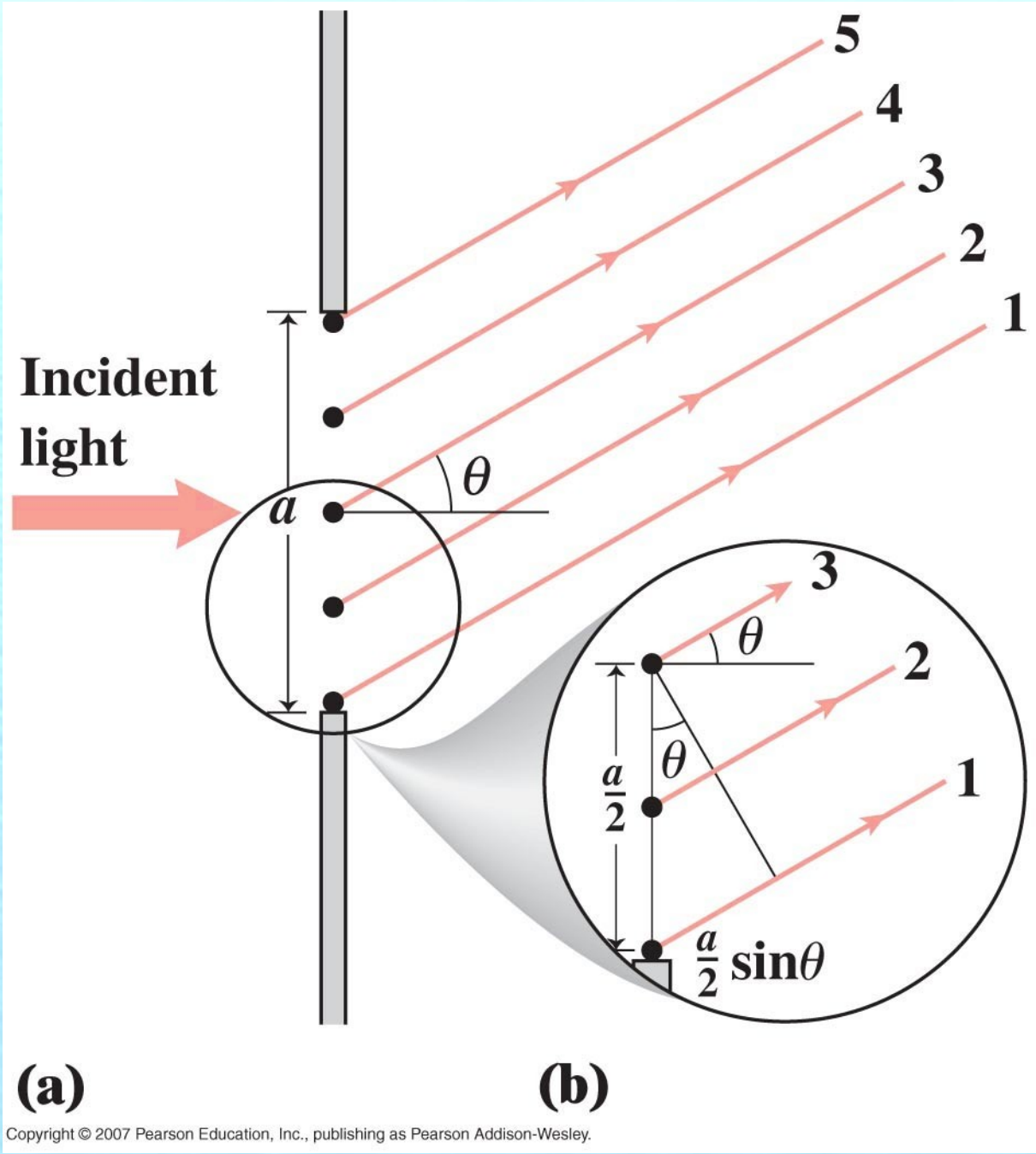
$$\tan\theta = \theta + 2\frac{\theta^3}{3!} + 16\frac{\theta^5}{5!} + \ldots$$

Single slit diffraction

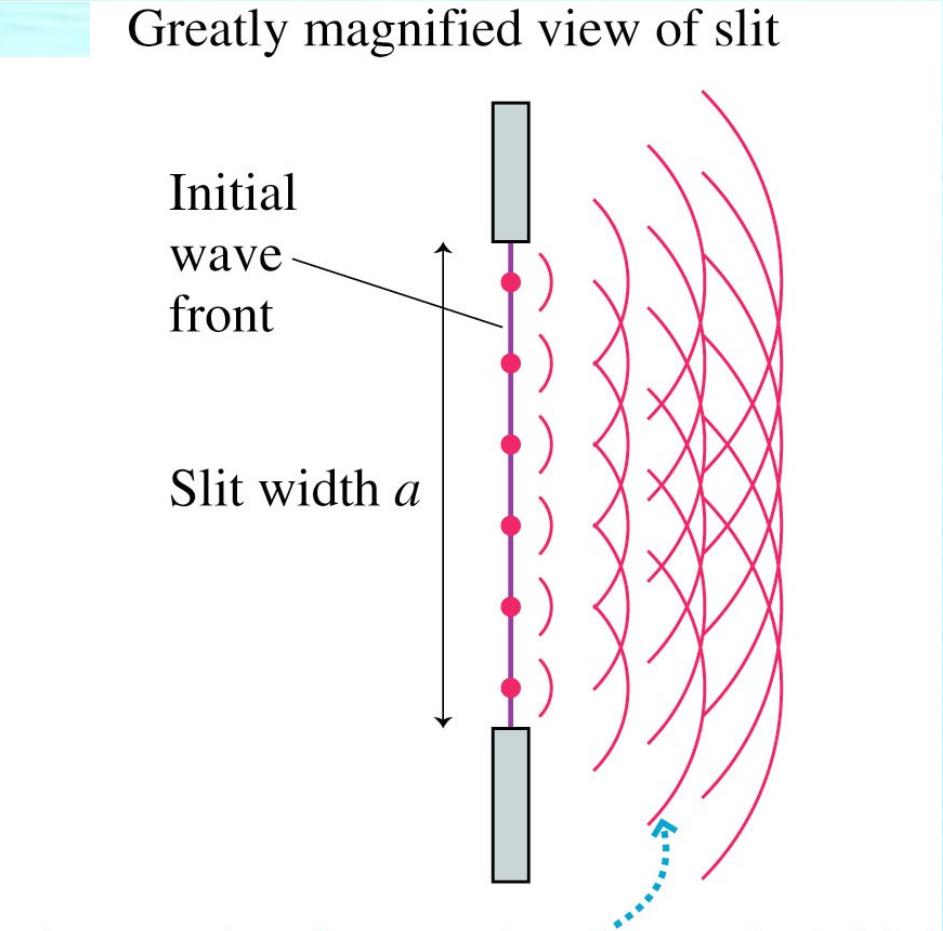
Light from different Parts of a single slit interferes with itself Destructive Condition:

$$\frac{a}{2}\sin\theta = \lambda/2$$

$$a\sin\theta = m\lambda$$



Analyzing Single-Slit Diffraction

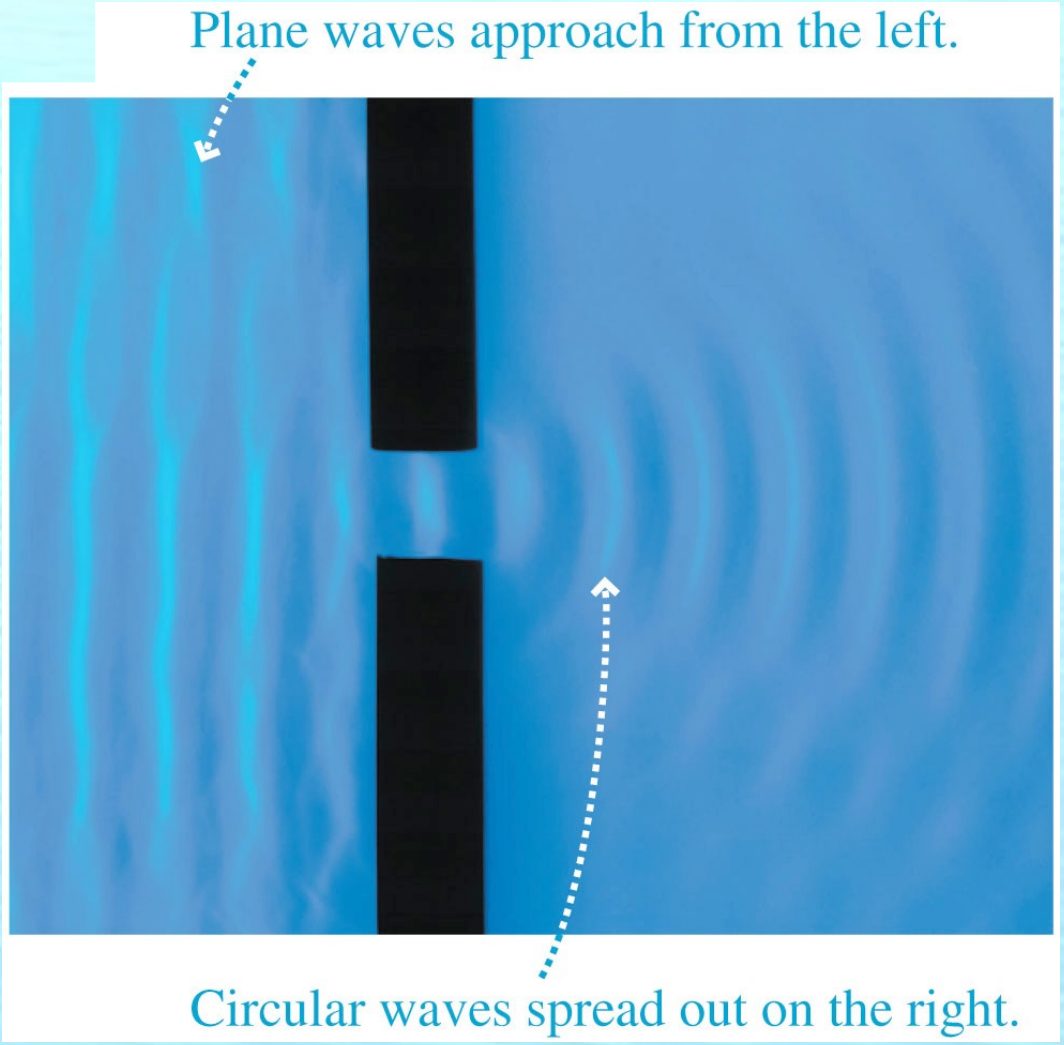


- The figure shows a wave front passing through a narrow slit of width a.
- According to Huygens' principle, each point on the wave front can be thought of as the source of a spherical wavelet.

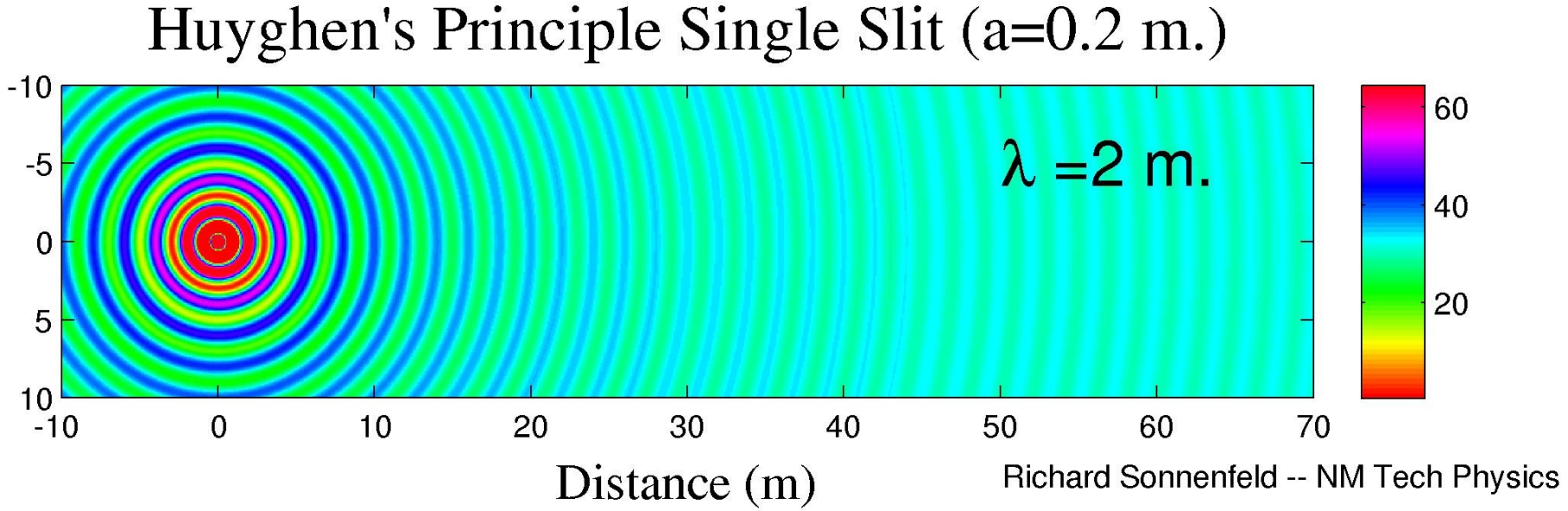
Huyghens Principle

- Every point on a wave

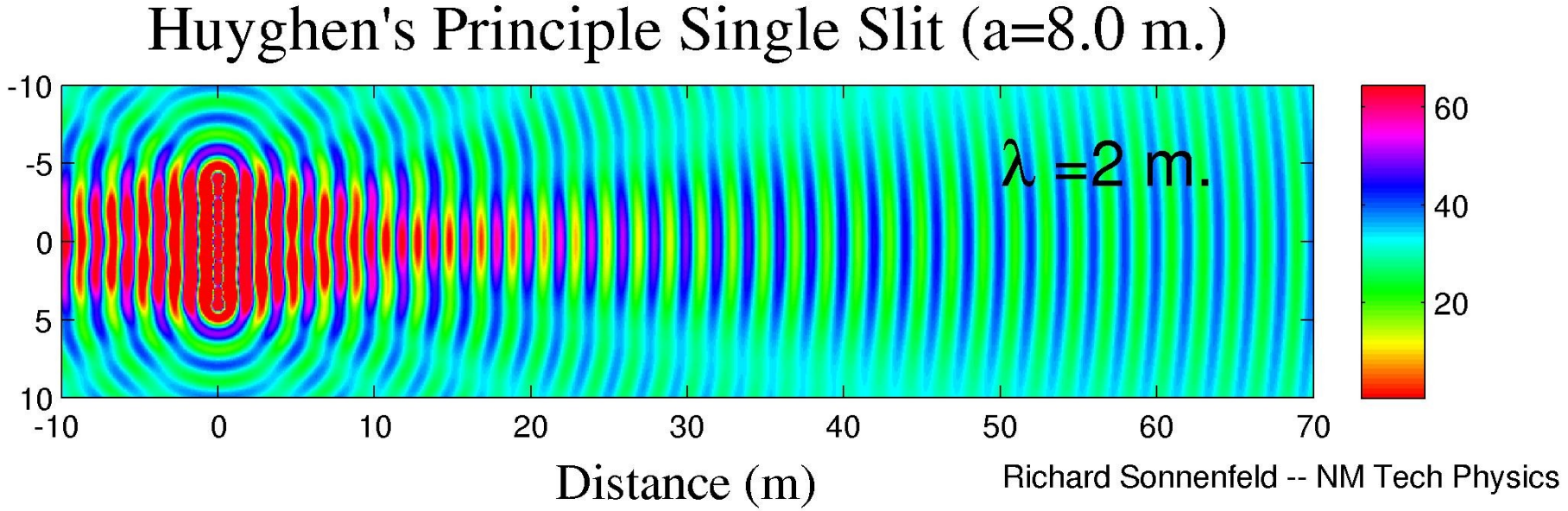
  can be considered a new source for a spherical wave.
- Add up all the spherical waves to find out what diffraction pattern you get.



Huyghens


Huyghen's Principle Single Slit (a=0.2 m.)
λ =2 m.
-10
-5
0
5
10
-10
0
10
20
30
40
50
60
70
60
40
20
Distance (m)
Richard Sonnenfeld -- NM Tech Physics

Huyghens


Huyghen's Principle Single Slit (a=8.0 m.)
λ =2 m.
-10
-5
0
5
10
-10
0
10
20
30
40
50
60
70
60
40
20
Distance (m)
Richard Sonnenfeld -- NM Tech Physics

Huyghens principle in action ...
watch time dependence of wave

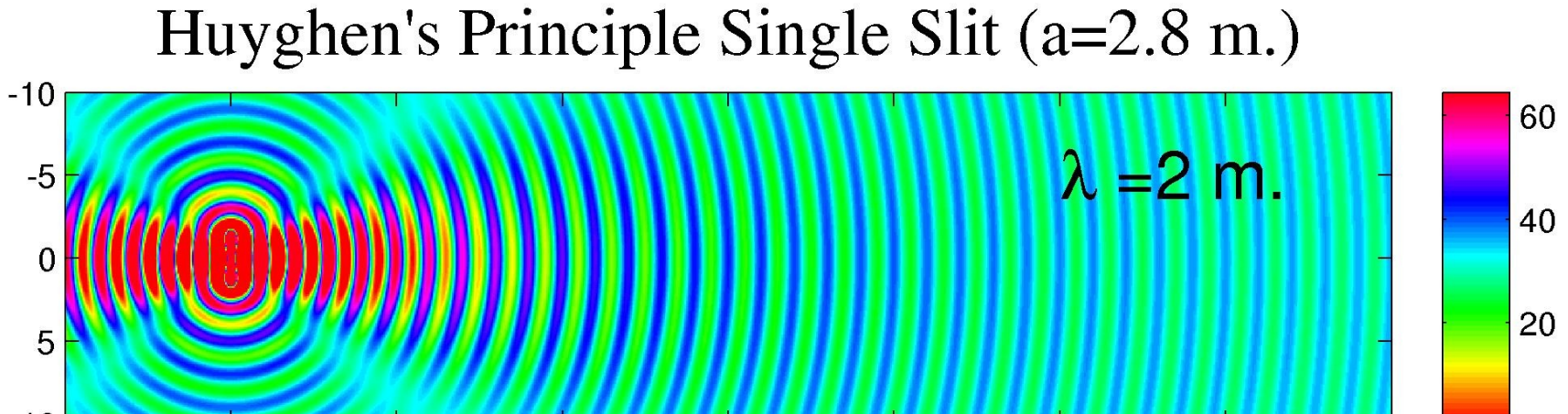
Single slit

A slit is 2.8 microns wide and an infrared laser with wavelength 2 microns shines through it. At what angle is the first null?

(A) 30 degrees
(B) 45 degrees
(C) 60 degrees
(D) 90 degrees
(E) There is no first null

Single slit

A slit is 2.8 m wide and a water wave with wavelength 2 microns passes through it. At what angle is the first null?



Single slit

A slit is 4 microns wide and an infrared laser with wavelength 2 microns shines through it. At what angle is the second null?

(A) 30 degrees
(B) 45 degrees
(C) 60 degrees
(D) 90 degrees
(E) There is no second null

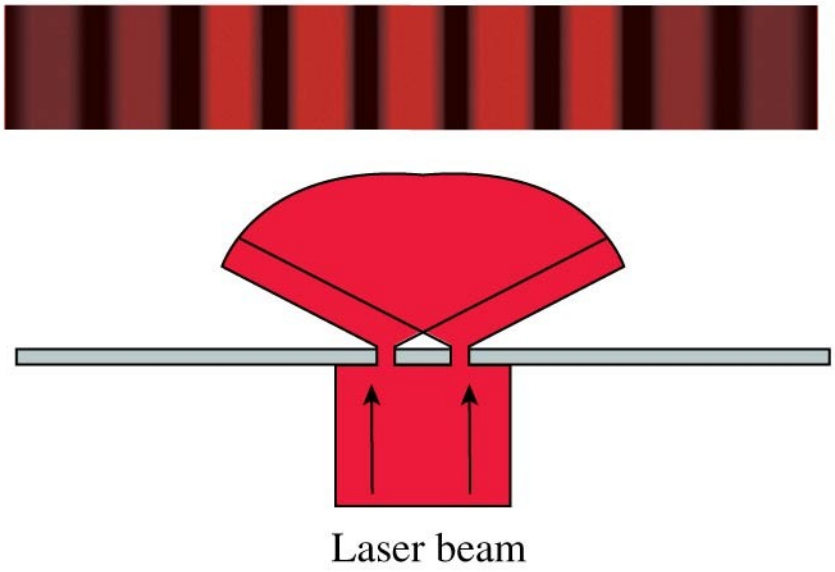
Single slit

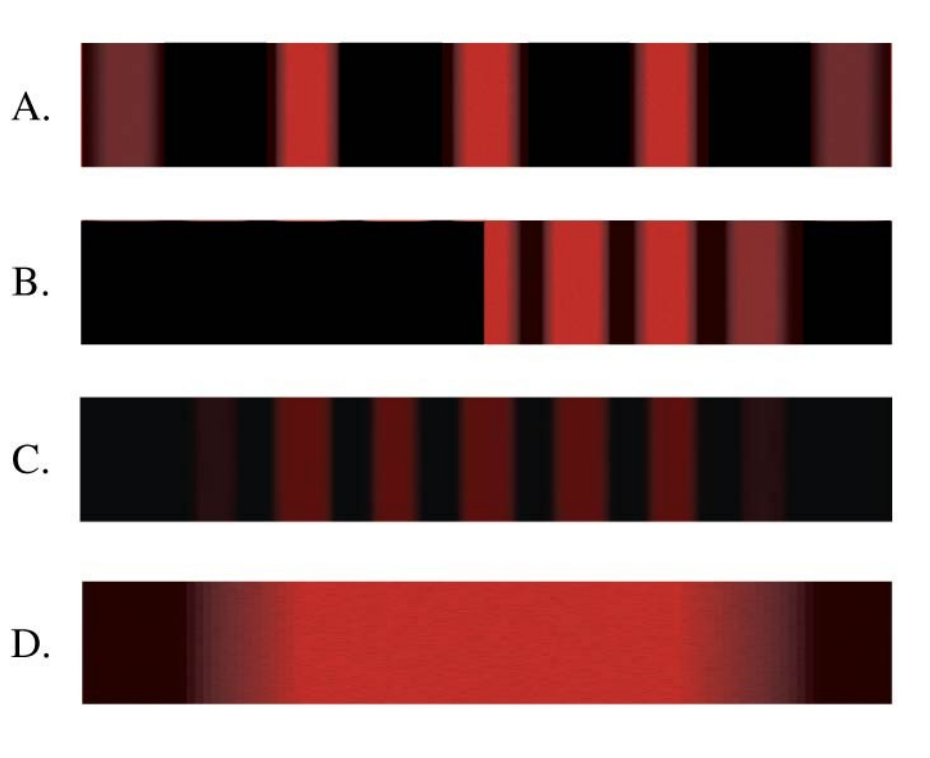
A slit is 4 microns wide and an infrared laser with wavelength 2 microns shines through it. At what angle is the third null?

(A) 30 degrees
(B) 45 degrees
(C) 60 degrees
(D) 90 degrees
(E) There is no third null

Clicker Questions

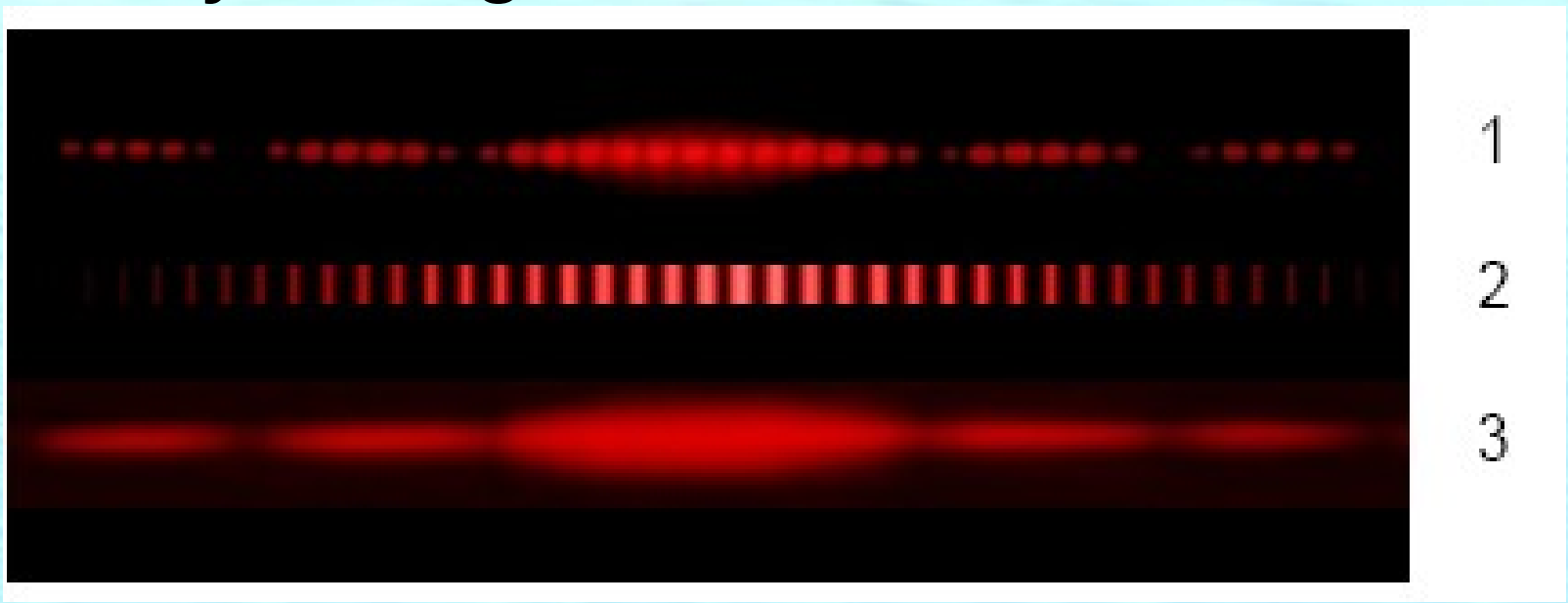
A laboratory experiment produces a double-slit interference pattern on a screen. If the left slit is blocked, the screen will look like





Clicker Question

Which of these interference patterns could be formed by a single slit?



(A) 1
(B) 2
(C) 3
(D) 1 and 2
(E) 2 and 3

Michelson Interferometer

Youtube tsgphysics michelson
LIGO Grav Wave Observatory

Can measure displacements a tiny fraction of wavelength of light.

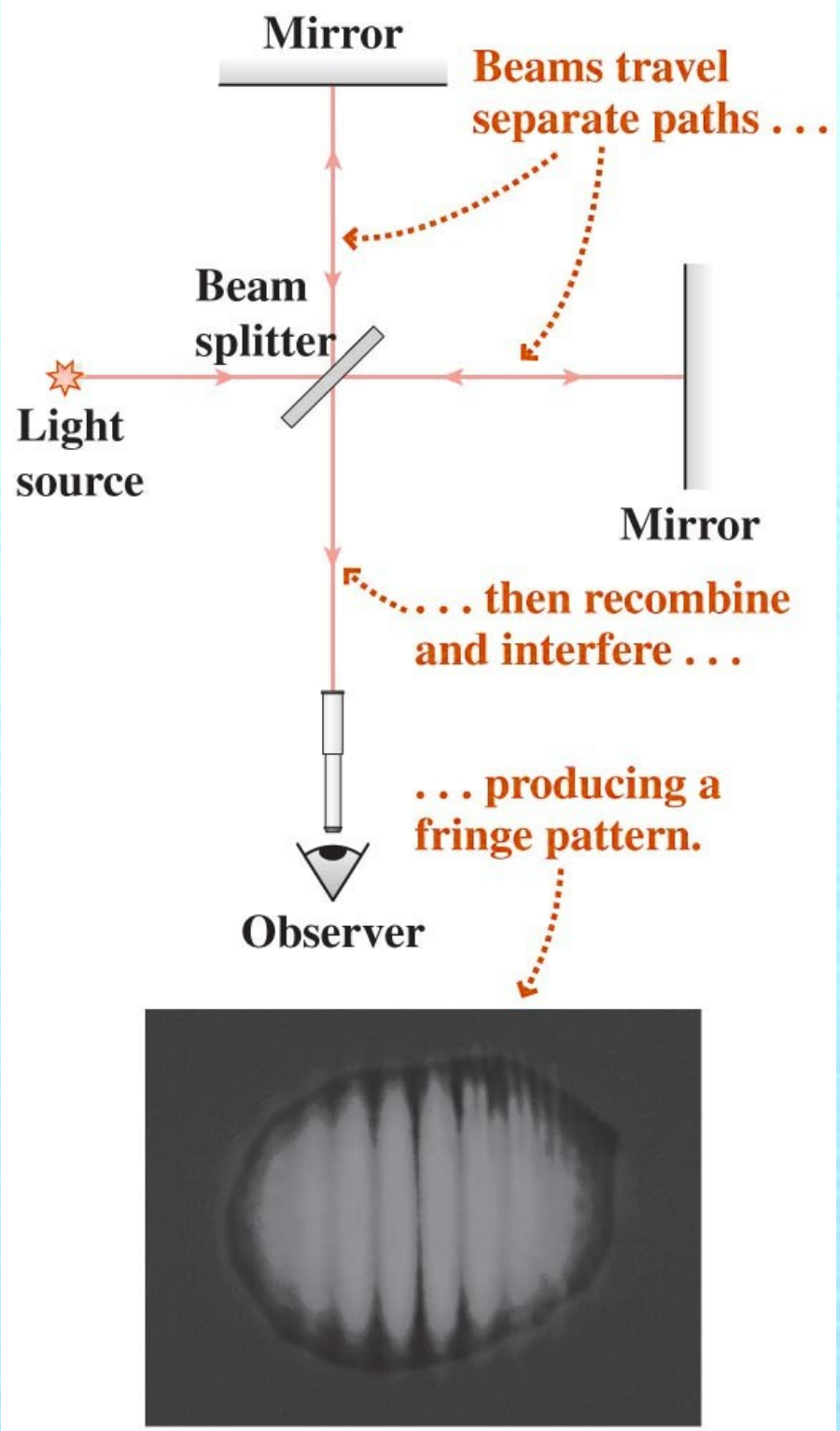
Apps:

Small indexes of refraction

Nano-controllers

grav-wave detection.

Relativity



Problems

Find the wavelength of light used in a Michelson interferometer if 550 bright fringes go by a fixed point when the mirror moves 0.15 mm.

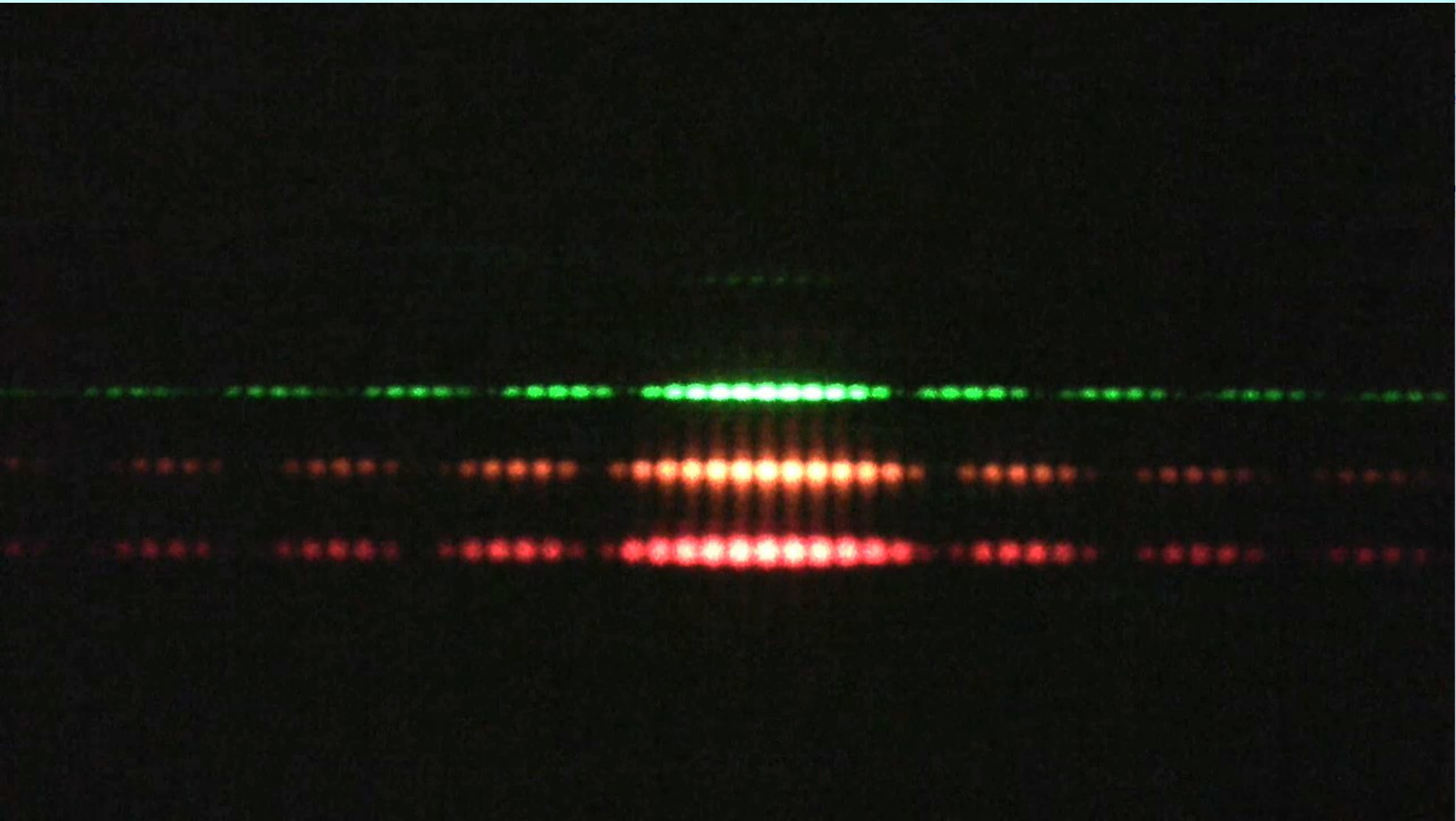
$$\Delta x = 2\Delta L \qquad \Delta x = m\lambda$$

$$\lambda = \frac{2\Delta L}{m} = \frac{2 \times 1.5 \times 10^{-4}\ \text{m}}{550}$$

Problems

22-65) One arm of a Michelson interferometer is 42.5 cm long and enclosed in a box that can be evacuated. 388 fringes pass a point when the air is pumped out. For 641.6 nm laser light, what is the refractive index of air?

Doubles slit diffraction is superposition of single and double slit



Ch. 22: Interference and Diffraction

$d \sin\theta = m\lambda$

Condition for constructive interference between slits separated by "d".

$a \sin\theta = m\lambda$

Condition for destructive interference for single slit of width "a".

In general: Phase difference of 2 pi m or path difference of lambda, constructive interference.